

National Weather Service's FLDWAV Computer Program

The FLDWAV program, developed by the National Weather Service (NWS), is a generalized flood routing program with the capability to model flows through a single stream or a system of interconnected waterways. FLDWAV, Version 1.0.0, released in November 1998, replaced the NWS generalized flood routing programs DAMBRK (released in 1988) and DWOPER (released in 1984). While DAMBRK has the ability to analyze the flow of a single stream, DWOPER has the additional capability to model flows through a system of interconnected waterways. In addition to the capabilities of DAMBRK and DWOPER, FLDWAV also has the ability to analyze flows in mixed-flow regimes. FLDWAV was created to execute in the DOS environment; however, FLDWAV may be run in UNIX workstations and mainframe computers with minimal changes to the source code, which is available at the NWS website. A menu-driven utility program, FLDGRF, is available to display output data generated by FLDWAV. An automatic calibration feature is available in FLDWAV, and the NWS states that to produce acceptable forecasts by FLDWAV, the model first must be calibrated to observed stages at gages within the study area.

Unsteady flow analyses are more suitable for floodplains affected by floodplain storage, flow regulation, and flood protection measures. FLDWAV is applicable to analyze such floodplains in the context of the National Flood Insurance Program (NFIP). Because the analysis of dam-breach floods is not included in Flood Insurance Studies (FISs), the breach-modeling feature of FLDWAV will not be used in hydraulic analyses for FISs.

Along with other unsteady flow models accepted for NFIP use, FLDWAV does not have the capability to compute a floodway based on the equal conveyance reduction criterion, as required in the NFIP.

FLDWAV, Version 2.0.0, released in June 2000, has the capability to analyze flow through divided channels. The solution algorithm for the non-Newtonian (mud/debris) unsteady flow model has been enhanced in Version 2.0.0. In addition, the NWS has released a menu-driven interactive data input utility program, FLDINP, which is currently undergoing beta testing.

The theoretical basis, modeling capabilities, other useful features, and limitations of the FLDWAV computer program and its application in the NFIP are summarized below.

Theoretical Basis of NWS FLDWAV

A four-point implicit finite-difference numerical solution of the complete one-dimensional St. Venant equations of unsteady flow and appropriate external and internal boundary equations form the basis for the floodplains simulated by FLDWAV. The boundary conditions supported by FLDWAV include dams, bridges, weirs, waterfalls, and other man-made and natural flow controls. In addition, FLDWAV allows the user to select implicit dynamic wave, explicit dynamic wave, implicit diffusion wave, or level pool solutions of the St. Venant equations of unsteady flow.

Modeling Capabilities

The FLDWAV computer program is designed to analyze large flood events usually caused by breach of a dam and to predict the movement of a large flood wave in the real-time forecasting done by the NWS River Forecasting System. FLDWAV has the following capabilities:

Flow system: FLDWAV can model single channel or dendritic systems, straight or meandering channels, or divided channels.

Flow regime: FLDWAV can model free surface flows in subcritical, supercritical, and mixed-flow regimes or pressurized conduit flows.

Fluid type: FLDWAV can model Newtonian (clear water) fluids and non-Newtonian fluids (mud/debris).

Off-channel storage: FLDWAV can define ineffective flow areas in cross sections to be used to model ineffective flow areas.

Flow Controls: FLDWAV can model time-dependent dam breaches, time-dependent gate controls, flow over spillways, flow through waterfalls and short rapids, pressure and weir flow of bridges and breaches of bridge embankments, low flows through bridge embankments, and multiple levee over-topping and breaches

Other Useful Features

FLDWAV has the capacity to interpolate cross sections.

FLDWAV can read rating curve data as input. This feature is generally available in unsteady flow models. This feature gives FLDWAV the capability to use the stage-discharge relationships of control structures developed by other hydraulic models/analyses or obtained through observation.

FLDWAV can use an optimization procedure to determine the Manning's roughness coefficients necessary to calibrate to observed high-water marks. This calibration is achieved through an efficient automatic adjustment of the roughness coefficients such that the differences between computed and observed water-surface elevations are minimized.

Model Limitations

Culvert flows: FLDWAV does not have a culvert analysis routine. In its current form, FLDWAV bridge analysis or pressurized flow analysis can be used to model culvert flows. However, culvert flows are more accurately modeled using the Federal Highway Administration (FHWA) nomographs based on lab testing results. The results of the FLDWAV model would be enhanced if the culvert flow characteristics were analyzed externally (using FHWA methods) and imported as a rating curve. The NWS plans to include a culvert analysis routine in the next version of FLDWAV.

Flow Through Storm Sewers: The current version of FLDWAV does not have the capability to model storm sewer junctions and energy losses associated with manholes.

Floodway Modeling: The current version of FLDWAV cannot define floodway stations based on equal conveyance reduction criteria.

Technical Support

Technical support for FLDWAV application problems is available through the NWS River Mechanics webpage at the following address: hsp.nws.noaa.gov/oh/hrl/rvrmech/rvrmain.htm.

FLDWAV and the NFIP

In the NFIP, the 10%, 2%, 1%, and 0.2% annual chance Flood Profiles and the delineation of the 1% and 0.2% annual chance floodplains and floodway of riverine flooding sources are generally determined using hydraulic computer programs capable of analyzing flows of streams and capable of considering control structures located in floodplains. Bridges and culverts are the control structures most frequently within floodplains. The flood elevations shown on FIS Flood Profiles can be read to an accuracy of 0.1 foot. In addition, FEMA defines floodways only for streams studied in detail. The floodways are generally defined based on equal conveyance reduction criteria.

The current version of FLDWAV can analyze general riverine floodplains (natural floods). Similar to DAMBRK, the features built into FLDWAV make it suitable to analyze large flows generally associated with dam breach events.

The limitations of FLDWAV discussed below should be considered before using FLDWAV to analyze floodplains for the NFIP.

- **Definition of cross section geometry**

The geometry of the channel and the overbank are represented in FLDWAV by cross sections. The cross-section geometry is defined by the relationship between the top width and its corresponding elevation. This method of defining the channel geometry is more suited to input data measured from a topographic map. The cross sections used in FIS models generally are more accurately determined by ground surveys and are usually defined as a horizontal distance and its corresponding elevation. The accuracy obtained by a ground survey may be lost while translating it to the format used in FLDWAV (top widths and corresponding elevations).

- **Modeling flows through bridges and culverts**

Care should be taken when analyzing floodplains with bridges and culverts. Similar to DAMBRK, FLDWAV can analyze the flows (pressure flow, pressure and weir flow) through bridges and long pipes. Until FLDWAV bridge analysis is expanded to analyze flows

through culverts, it is recommended that the use of FLDWAV in the NFIP be limited to floodplains unobstructed by bridges and culverts. However, the use of FLDWAV can be extended for floodplains with bridges and culverts, if the discharge characteristics of control structures are developed using NFIP-accepted methods and imported into the FLDWAV model as a rating curve.

Use of FLDWAV to Revise Effective DAMBRK FIS Models

The following guidelines are recommended for the use of FLDWAV to revise effective DAMBRK analyses:

- If only a portion of the floodplain is revised, for convenience (to have one FIS hydraulic model instead of two) DAMBRK should be used for the analysis.
- If the entire floodplain is revised, FLDWAV should be used to create the new model.

In addition, floodplains studied using approximate methods of analyses can be revised on the basis of existing DAMBRK analyses prepared as part of other watershed studies. However, if a new analysis is conducted to define flood elevations for a FIS and FIRM, FLDWAV should be used.